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Section: Radiology Section Chief: Hymer L. Friedell, M.D.

A SCINTILLATION COUNTER FOR MEASUREMENT OF I^{131} UPTAKE IN THE THYROID GLAND

by

William J. MacIntyre

Submitted by: Hymer L. Friedell, M. D.
Director

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Abstract

A scintillation counter for detection of I^{131} uptake in the thyroid gland has been constructed and described. Improvement over the conventional Geiger counter and scaler set-up as previously used has been achieved by a factor of 30 ∼ 50 in sensitivity. A six week period of clinical use of this counter is compared with the use of the Geiger counter. A discussion of the response of various phosphors to the gamma rays of I^{131} is included along with a description of the equipment employed.

A SCINTILLATION COUNTER FOR MEASUREMENT OF I^{131} UPTAKE IN THE THYROID GLAND

William J. MacIntyre

INTRODUCTION

The uptake of I^{131} by the thyroid is usually measured by a combination of a conventional Geiger counter and scaling circuit (1). In this case, as in most cases of *in vivo* assays of radioisotopes used for therapeutic purposes, the measurements are accomplished by detection of gamma rays, which undergo very little absorption in passage through a small amount of tissue.

The problem inherent in this type of measurement is threefold: First, the detector cannot be placed in close proximity to the neck, since for accurate estimates the counter must be able to view the entire gland and detect activity originating in any part thereof. This necessitates counting at a fixed distance from the neck, usually six to twelve inches, and results in a deliberate low geometric efficiency.

Second, large tracer doses cannot be given in order to obtain higher counter rates because of health hazards.

Third, the efficiency of a Geiger counter for detection of gamma rays of I^{131} is low, usually estimated at a value of 0.1% to 1% detection of incident gamma rays from this isotope.

The high efficiency of scintillation phosphors to the detection of gamma rays (2,3,4) has made their application to this problem an obvious subject of investigation.

COMPARISON OF RESPONSE OF VARIOUS PHOSPHORS TO GAMMA RADIATION OF I^{131}

Much work has already been done on the relative response of various scintillation phosphors (5). However, since various phosphors seem to exhibit different relative efficiences for different types of radiation (6) it seemed advantageous to determine the response of some of the more common commercially available crystals to the gamma radiation of I^{131}. Assuming the decay scheme of Metzer and Deutsch (7) this response would then be that arising from a beam of gamma rays 79% of energy 0.363 Mev, 15% of energy 0.638 Mev, and 6% of energy 0.283 Mev and 0.080 Mev.

In this work five phosphors (anthracene, naphthalene, naphthalene with anthracene activator, 0.1% thallium-activated potassium iodide, and dihydro-anthracene)[1] were compared by means of integral bias curves, plotting counting rate versus integral pulse height. The units of pulse height are arbitrary, since they are a function of amplification and not the magnitude of actual pulses received from the electron multiplier tube.

The phosphors were mounted on the end of a 5819 electron multiplier tube and exposed to the same source of I^{131} at identical geometric and electronic conditions. Pulses from the tube were fed from a cathode follower preamplifier to a linear amplifier[2], discriminator[2] and scaler. The electron multiplier was operated at room temperature, and at approximately 800 volts. Noise counts from the tube amounted to about one-tenth the total count and were subtracted from each reading.

[1]All obtained from Harshaw Chemical Company, Cleveland, Ohio.

[2]Linear Amplifier, Model 204-B, Atomic Instrument Company, Boston, Mass.

The comparison curves as shown in Figure 1 indicate anthracene to have the optimum pulse distribution. The potassium iodide crystal (Tl) shows a higher efficiency, as expected over the organic crystals because of greater density, but a smaller number of large pulses. Recently some 0.5% thallium-activated potassium iodide crystals[1] have been available and show an efficiency roughly four times higher than those with the smaller amount of thallium. A comparison of both potassium iodide (Tl) crystals with anthracene is shown in Figure 2.

The use of potassium iodide (Tl) crystals would be advantageous where low bias levels could be utilized were it not for the presence of naturally radioactive K^{40}. Assuming a 0.011% incidence of K^{40}, a cubic centimeter crystal of potassium iodide would have approximately $\sim$1000 disintegrations per minute, thus making this phosphor of little use for low activity assays. For the remainder of this work, anthracene was used throughout.

RECORDING CIRCUITS

Since the counting equipment was intended for clinical use, the recording circuits were selected with the view towards simplicity, commercial availability, and flexibility. Much of the work with scintillation counters by previous investigators has involved the reduction of tube noise by cooling with dry ice or liquid nitrogen. This was not attempted since the method was considered too unwieldy for clinical procedure. Operation of the tubes at room temperature and adjustment of the bias to eliminate the larger part of the noise such as accomplished by Cassen, Curtis, and Reed (8) was attempted. With the phosphors and tubes chosen, however, the stability and sensitivity desired was not obtained by this procedure.

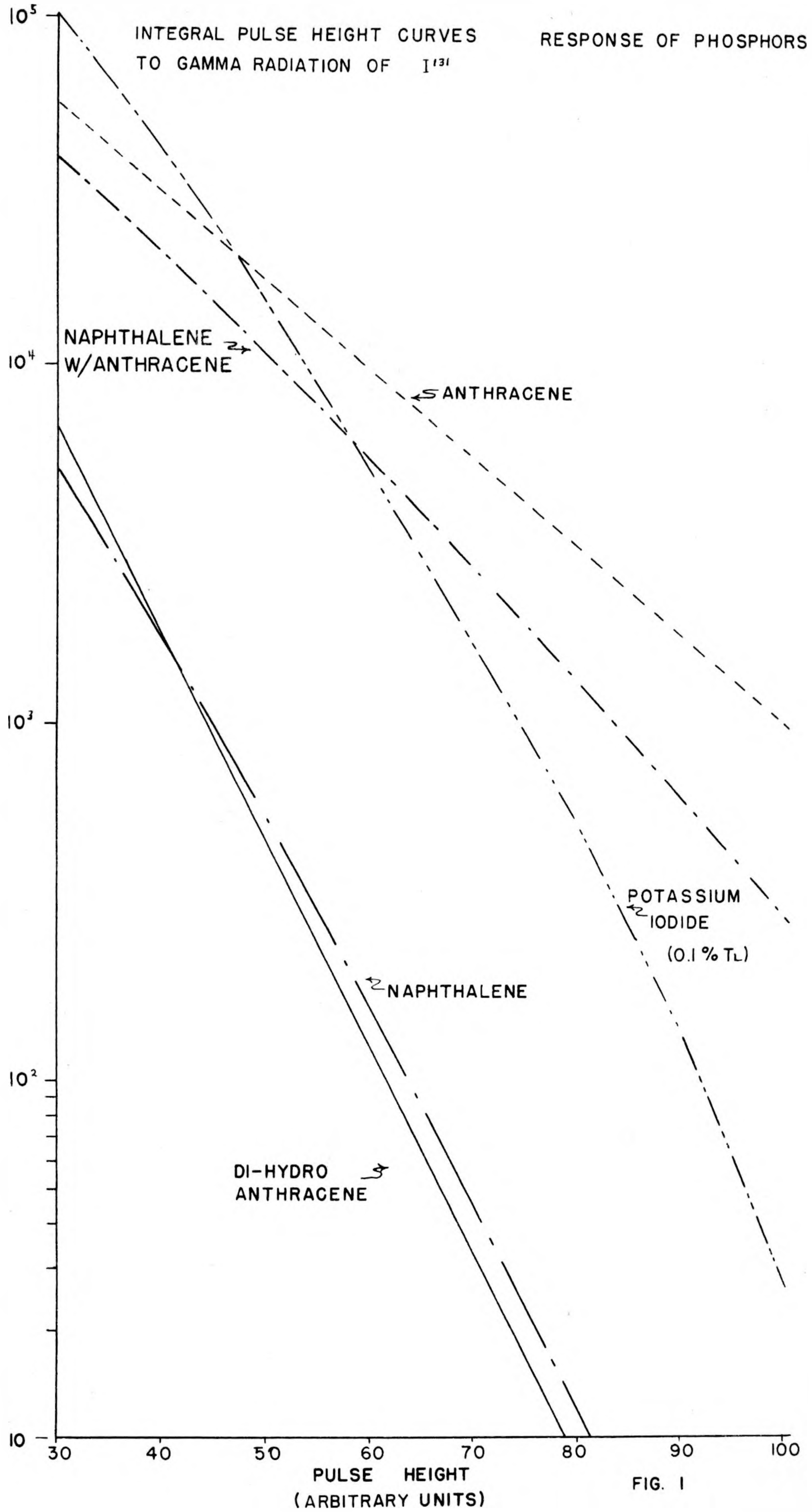

INTEGRAL PULSE HEIGHT CURVES
TO GAMMA RADIATION OF I131
RESPONSE OF PHOSPHORS
10⁵
10⁴
10³
10²
10
NAPHTHALENE
W/ANTHRACENE
ANTHRACENE
POTASSIUM
IODIDE
(0.1 % TL)
NAPHTHALENE
DI-HYDRO
ANTHRACENE
30
40
50
60
70
80
90
100
PULSE HEIGHT
(ARBITRARY UNITS)

FIG. 1

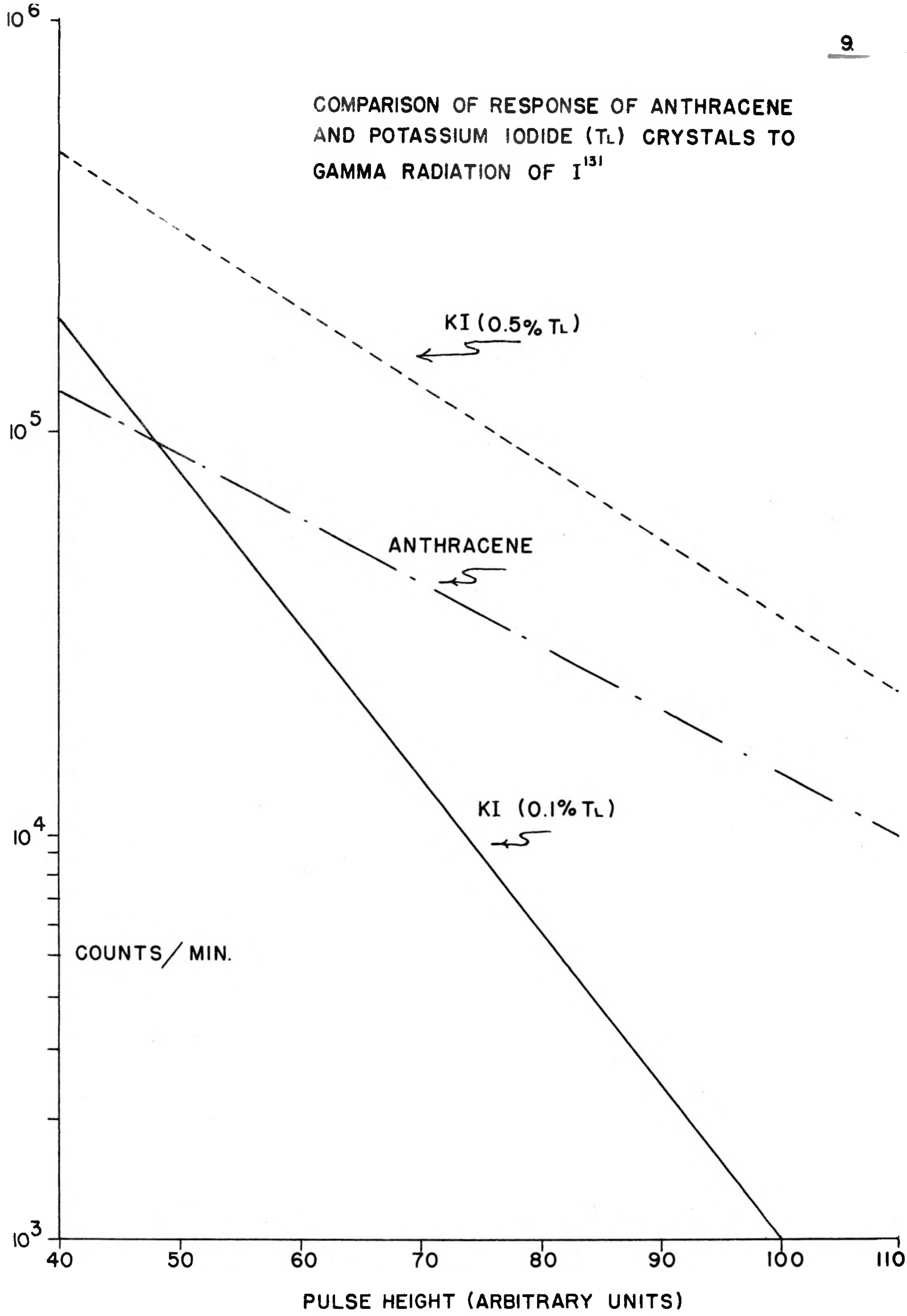

COMPARISON OF RESPONSE OF ANTHRACENE AND POTASSIUM IODIDE (TL) CRYSTALS TO GAMMA RADIATION OF I131
KI (0.5% TL)
ANTHRACENE
KI (0.1% TL)
COUNTS/ MIN.
10 6
10 5
10 4
10 3
40
50
60
70
80
90
100
110
PULSE HEIGHT (ARBITRARY UNITS)

FIG. 2

Instead, the method of using two electron multiplier tubes to view the same crystal and reducing background noise by a coincidence circuit was selected. This fulfilled the requirements of simplicity and commercial availability since small amplifiers together with a coincidence circuit, have been recently manufactured[3]. These units are small and compact and have given no trouble in operation. The power supply as provided with this unit is unregulated, however, and because of the instability of the power line and the large amount of transient electrical noise pulses, separate power supplies were constructed and employed.

The high voltage negative supply was modeled after the circuit of Bair and St. John (9). This embodies a high frequency filter for the transient electrical noise and isolation from all grounds except at the output terminal to inhibit ground currents. The regulation is accomplished by miniature voltage regulator tubes. The low voltage power supply was a conventional regulated power supply based on the supply used for the linear amplifier of Jordan and Bell (10). This combination has performed satisfactorily with the coincidence amplifiers and has presented no problems of stability. The output of the coincidence circuit is fed to a scaling circuit of a negative 0.25 volt input.

DETECTOR HEAD

The detector head was designed to place the scintillation phosphor as close as possible to the 1P21 electron multiplier tubes and to eliminate any air-solid interface which might reflect the scintillations back into the crystal. To do this, the tubes were first placed with their cathodes at right angles and the tube bases

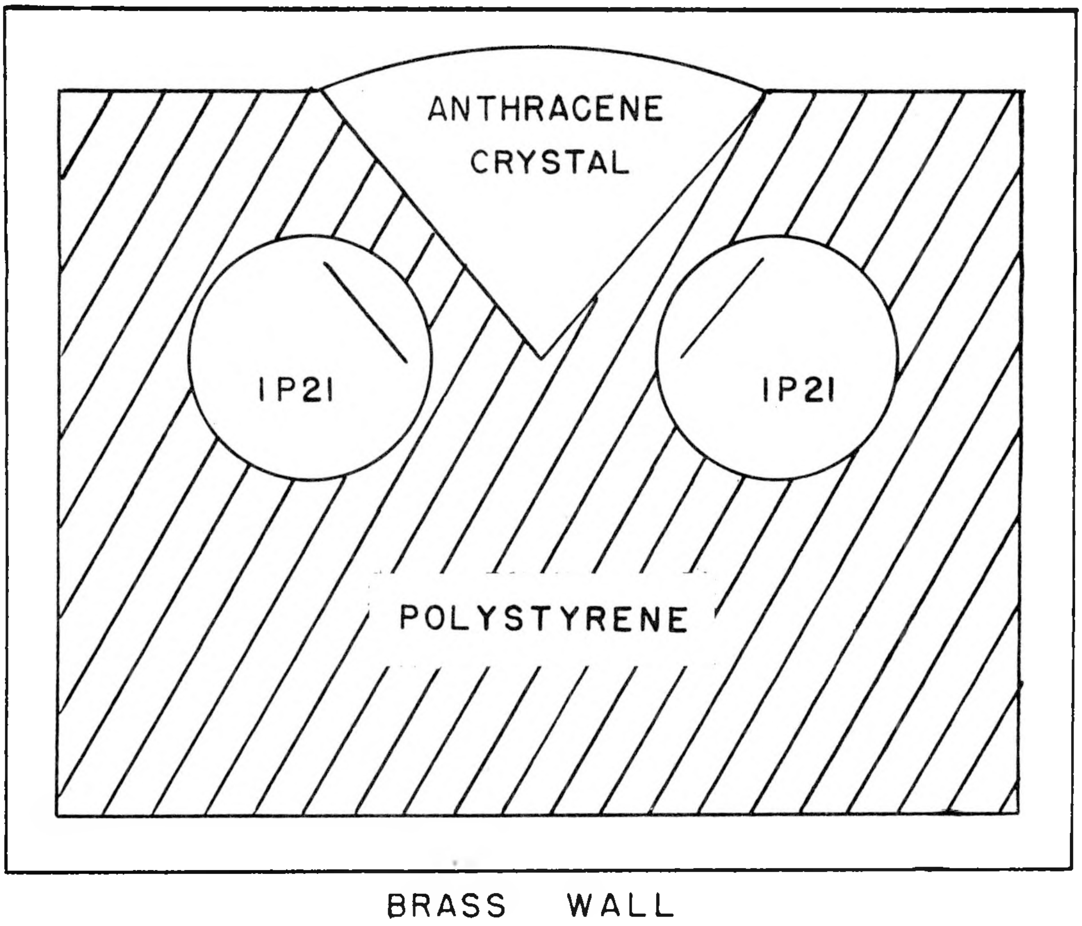
[3]Coincidence amplifier Type 152A W. S. MacDonald Co., Inc., Cambridge, Mass.

in contact with each other. Over this a polystyrene block was mounted with two holes for the tube and a right angled cut placed within one-eighth inch of the tube. The phosphors were then cut at right angles, polished, and placed in the right-angled groove in contact with the polystyrene. This is shown in Figure 3. The air-solid interfaces are then kept at a minimum and can be entirely eliminated for permanent mounting by cementing the crystal and tube face to the polystyrene with some substance such as Canada balsam. This also keeps the phosphor close geometrically to both cathodes of the 1P21's.

The output from the detector head is fed by a four foot cable to the amplifiers and has given satisfactory results operated in this manner. However, a preamplifier has been constructed and tests are underway to investigate possible improvements. The cathode follower preamplifier, as shown in Figure 4, presents a low capacitance to the anode and thus should give a larger pulse to the amplifier. This is consistent with results since it has been noted that the tubes may be run at voltages of 650 ~ 750 instead of the usual 850 volts. The investigation of actual improvements in counting efficiency by addition of the preamplifier has not been completed and the following measurements have been taken with direct coupling from the anode of the electron multiplier tube to the amplifier.

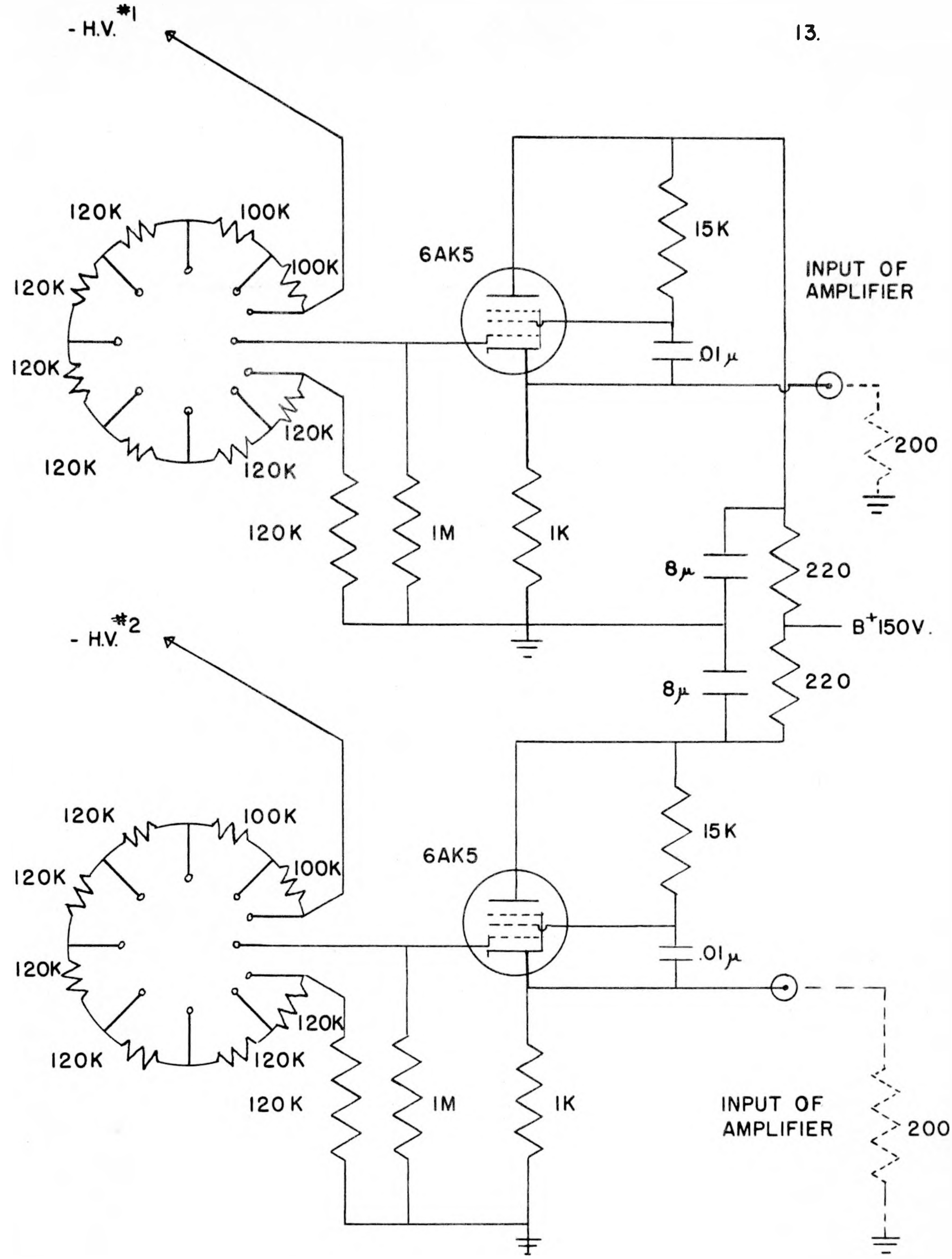
CLINICAL MEASUREMENTS

In the preliminary clinical measurements for uptake of I^{131} in the thyroid gland a triangular anthracene crystal with an outer face of dimensions, two inches by one-half inch, was mounted



SCHEMATIC DIAGRAM OF DETECTOR HEAD

FIG. 3



DOUBLE ELECTRON MULTIPLIER PREAMPLIFIER FOR SCINTILLATION COUNTER

FIG. 4

as shown in Figure 3. In a comparison with a brass walled Eck and Krebs type Geiger counter and a conventional scaling circuit combination as used in the Department of Radiology, University Hospitals, Cleveland, Ohio, an improvement in sensitivity by a factor of 30 to 50 has been obtained. The Geiger counter is shielded by one inch of lead with a one inch diameter hole centered above the gland.

As the sensitivity is a function of bias adjustment on the operation of the coincidence circuit the factor of sensitivity improvement is rather arbitrary. The optimum condition of operation has not yet been determined and at the present time the sensitivity selected is mainly determined by the counting rate to which the background is to be restricted.

In the six week period that this counter has been in operation, the uptakes of I^{131} in the thyroid glands of 23 patients have been measured and compared with the standard dose of 50 μc used. The average counting rate of the standard was found to be 13,490 c/m with an average uptake rate of 5,908 c/m. In the three months preceeding the use of the scintillation counter, the standard Geiger counter as previously described was used. For 23 patients given a 200 μc dose the average uptake was 403 c/m with an average counting rate of the standard of 710 c/m. Thus the counting rate was increased by a factor $15 \sim 19$ although the dose was decreased by a factor of four.

The ratios of the average uptake to average standard with the two different dosages and measurement are not identical. This is due to the fact that the 50 μc dose was given to individuals, many of whom were normals, while the 200 μc dose was given only to the patients who were to receive a therapeutic dose of I^{131}. These were thus expected to show a higher uptake of I^{131} and the average uptake would then be expected to show a higher percentage uptake than that of all patients.

Although for routine clinical measurements the counting rates of the standard and the thyroid at one fixed distance are taken, some measurements were taken on the same patient at various distances.

A typical measurement at various distances is shown in the following table:

Distance (in.)	Standard	Uptake in Thyroid Gland c/m	Percentage Uptake in Thyroid
16.5	4,208	1,644	39.1
13.5	6,492	2,466	38.1
10.5	10,166	3,831	37.8
7.5	20,062	7,902	38.4

Background 175 c/m

A comparison of the same standard counted by both Geiger counter and scintillation counter is recorded below.

Distance (in.)	Geiger Counter c/m	Scintillation Counter c/m
16.5	174	4,208
13.5	249	6,492
10.5	423	10,166
7.5	737	20,062

Background 175 c/m

A comparison of the two counting rates is shown in Figure 5 in which the counting rate is plotted versus the inverse square of the distance. At a distance of 7.5 inches, the Geiger counter is seen to deviate from the inverse square law while the scintillation counter is still accurate. The standard of I^{131} was measured in the above case in 50 cc. of water to approximate roughly the conditions of actual measurement.

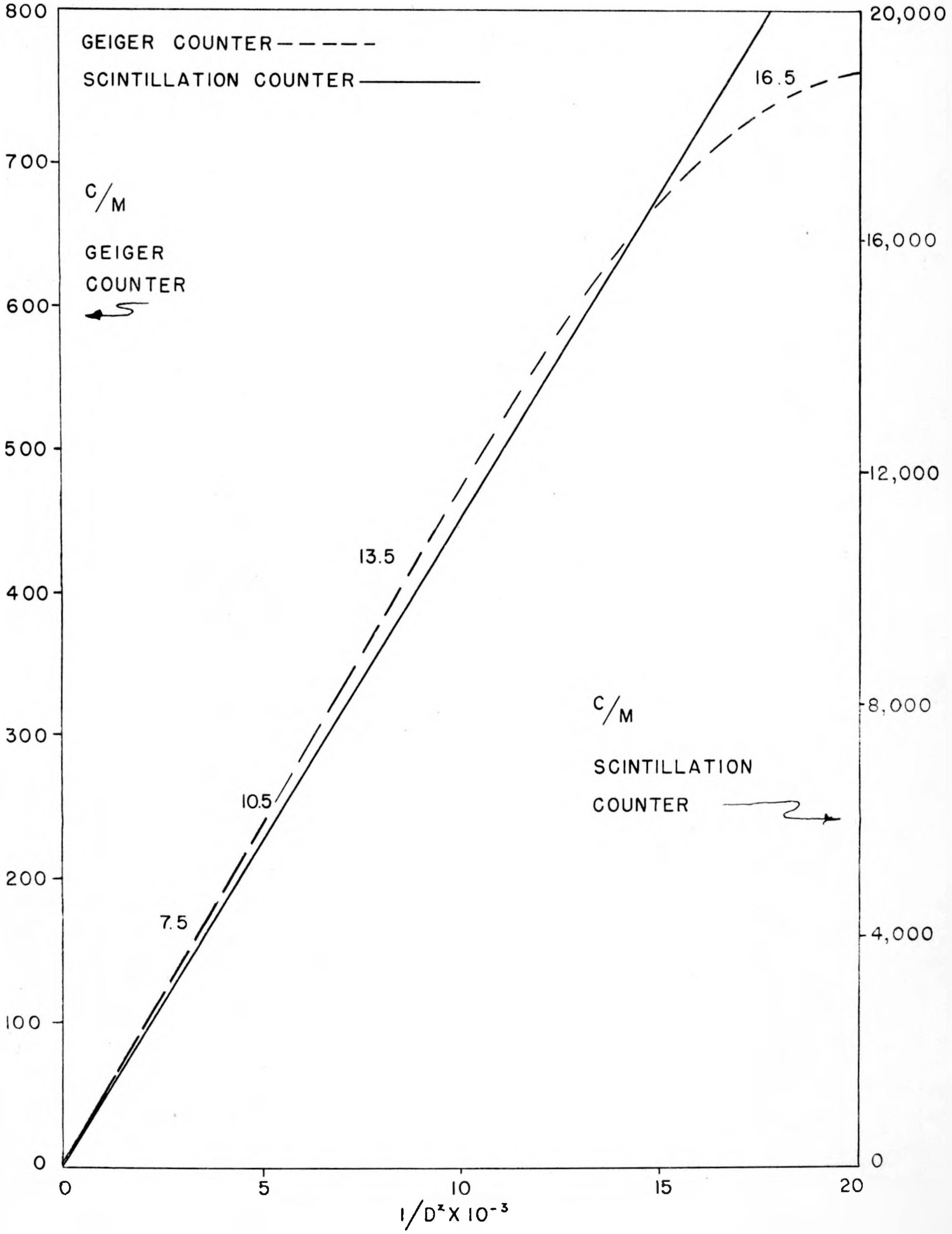
This sensitivity has allowed an immediate reduction of the tracer dose from 100 μc to 50 μc, with a recent reduction to 25 μc. It may be seen that the dose could be reduced to 10 μc with considerable ease. At the same time a decided improvement over the Geiger counter in counting statistics has been obtained. Based on the previous counting rates the 10 μc standard would exhibit a counting rate ∼ 2,700 c/m and an uptake rate ∼ 1,200 c/m. Background for such measurements would be 200 ∼ 400 c/m.

At the present time work is being initiated to reduce error in the uncertainty of size and position of the thyroid gland. This problem has already been attacked by Freedberg, Ureles, and Van Dilla (11) and by Hertz, et al (12) by using a method of placing four or more Geiger counters around the neck. The total counting rate is then independent of variations of position and size of the thyroid.

In the proposed scintillation counter a round lucite tube is to be constructed in the shape of a semi-circle, the center hollowed and filled with the scintillation phosphor. The lucite tube is then mounted with its midpoint at the juncture of the two 1P21 electron multiplier tubes, and the same recording apparatus as described for the previous counter is used. This will then give

COMPARISON OF SCINTILLATION AND GEIGER COUNTER DETECTION AT VARIOUS DISTANCES

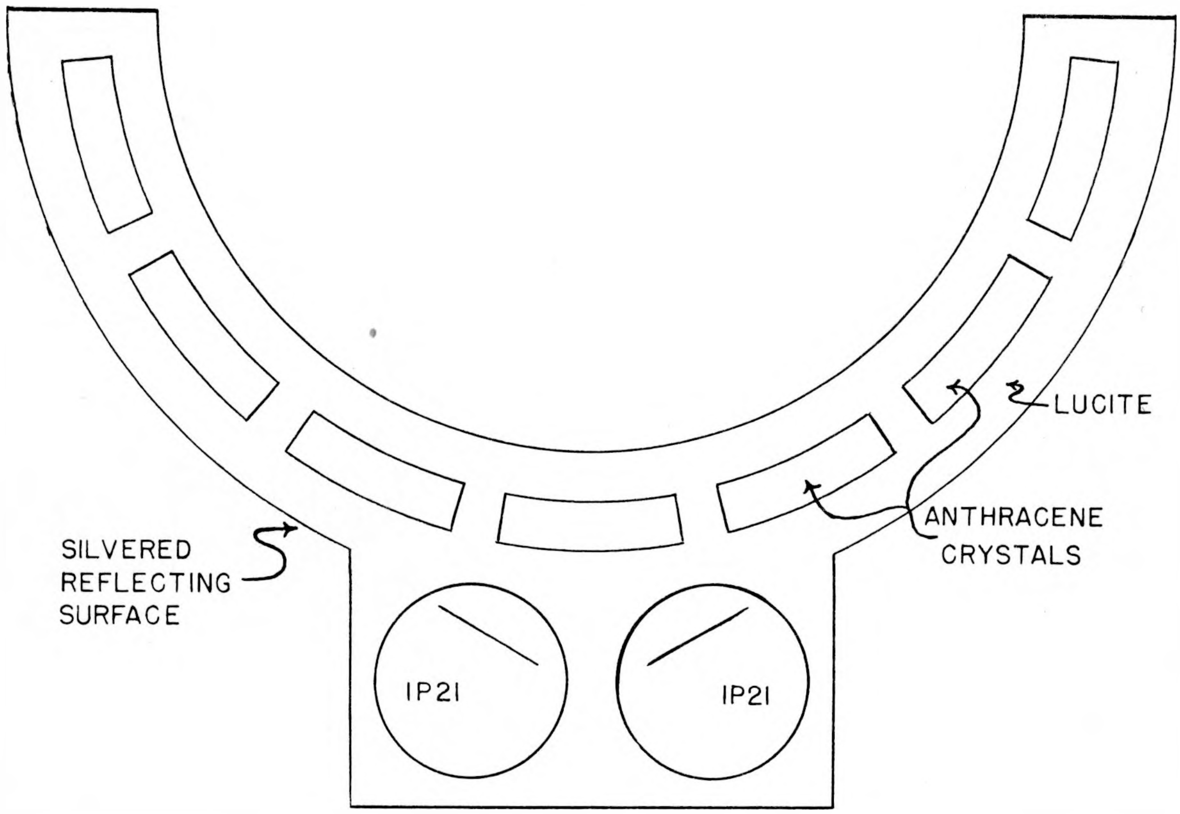
FIG. 5



a large geometric reception and a degree of independence of gland placement. The proposed arrangement is shown schematically in Figure 6.

Other applications of scintillation counters being investigated include designs adaptable for use in low activity assay for blood volume and circulation studies.

The clinical measurements in this work were made by John P. Storaasli, M.D.; Mr. William A. McCarthy and Miss June Dockery performed the phosphor response and test measurements.



SCHEMATIC DIAGRAM OF PROPOSED "COLLAR TYPE" SCINTILLATION COUNTER FOR I^{131} UPTAKE IN THYROID GLAND

FIG. 6

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